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Assessment of GHG emissions and their variability of meat production systems in Wallonia based on grass and maize

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Abstract

Within the framework of the Optenerges project, funded under the Interreg IV program, the greenhouse gas (**GHG**) emissions of 62 cattle farms representative of the main production systems in the Province of Luxembourg in Wallonia, Belgium were assessed. The main goal of this study was to give reference values for GHG emission intensity in meat production systems based on grass **(G)** and on grass and maize (**G-M**). A second goal was to analyze emission variability in order to identify potential mitigation options. On average, for every kg live weight the G systems emitted 18.2 CO_2 eq.. and the G-M systems 19.2 CO_2 eq.. The difference reflected differences in feed and mineral fertilizer purchases, in manure emissions and in mineral fertilizer application. There were large variations in GHG emissions both between and within the two systems, particularly the latter. This variability was not due to the division of the farms into G and G-M systems, indeed production system types did not allow explaining the variation. When carbon credits were included in the assessment, there was an emission reduction of 31% and 23% for the G and G-M systems, respectively, indicating an opportunity for the systems using grassland to increase their advantage.

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Keywords: GHG emissions; carbon footprint; efficiency; meat production; system approach.

1. Introduction

The environmental impact of agricultural systems, especially livestock breeding systems, has become an issue of public concern, among other, due to their greenhouses gas (**GHG**) emissions, particularly methane (CH_4) and nitrous

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oxide (N_2O) originating from rumination and manure management.

In 2012 in the world, agriculture was responsible for 11.2% of total GHG emissions (Tubiello et al., 2015) and these agricultural GHG emissions showed an upward trend (+1% from 2011 to 2012), although they did not rise as fast as GHG emissions from other human activities. There are important regional differences, too (e.g., agricultural GHG emissions grew fastest in Asia, but decreased in Europe). In Wallonia, the agricultural sector is responsible for 13% of the total GHG emissions, with the CH_4 and N_2O emitted by the sector representing 78% of the total regional emissions of these two gases (AWAC, 2015).

On the positive side, agriculture can play an important role in mitigating GHG emissions globally through carbon storage in grassland soils (Meersmans et al., 2010; Soussana et al., 2007), which occupy about 50% of the agricultural area in Wallonia, and through biomass production (it has been estimated that miscanthus and short willow rotation in Wallonia represent a potential of 1010 Gwh/year; Valbiom, 2010).

At farm level, there are various management options for reducing GHG emissions (Pellerin et al., 2013). The farm should be considered as a whole system, including the impacts of inputs production, in order to ensure that interactions between the various components (e.g., soil, crop, manure, feed, cattle) and their effect on GHG emissions are taken into account (Schils et al., 2007; Weiske et al., 2006).

The importance of assessing GHG emissions at farm level is indicated by the huge variability existing between farms (Mathot et al., 2014; Lioy et al., 2012) and the relatively high environmental impact of the production stage of processed agricultural products (Poritosh et al., 2009; Weidema et al., 2008; Basset-Mens et al., 2007). Calculating GHG emissions also highlights opportunities for reducing emissions and provides information on the carbon footprint of agricultural products.

The main goal of this study was to provide reference values for GHG emissions related to production in meat production systems based on grass and on grass and maize in Wallonia. A second goal is to analyze the variability in these emissions in order to determine practicable mitigation options.

2. Material and methods

Within the framework of the Optenerges project, funded by the INTERREG IV program, data from 62 cattle farms in the Province of Luxembourg in Wallonia, Belgium were collected in 2008 and 2009. The farms were representative of the main production systems in this area and were classified according to a typology based on the GENETYP method (Landais, 1998; Perrot, 1990), adapted for Wallonia (Hennart et al., 2010). Functional types were defined partly according to the ratio of grass and maize used to feed animals. In this study, the farms were divided into two systems: meat production based on grass (**G**) or on both grass and maize (**G-M**).

GHG emissions were estimated using a method developed by CONVIS (an agriculture cooperative society in Luxembourg), which uses emission factors in the literature (Lioy et al., 2012) and considers emissions from three sources: inputs; cattle breeding and crop production for animals (e.g., forage, cereal for feed). Carbon credits due to measures taken to increase carbon sequestration (e.g., no-till, conversion of cropland to grassland; Vesterdal and Leifeld, 2010) are included, using reference values from the literature (Lioy R., 2012). The production of renewable energy on farms (e.g., heat and electricity from biogas production, colza for biofuel production) that replaces the use of conventional energy is also taking into account (Lioy R., 2012).

Where a farm is producing several products (e.g., milk and meat), this method enables the GHG emissions from the different herds to be identified. In this study, however, the results refer only to meat production from a suckler-cow herd system and the associated land occupation. The emissions were measured in relation to live weight (**LW**) production and to land occupation (farm hectarage used).

Carbon storage in grassland soils was added as a credit based on values used in the literature: 500 kg C/ha for permanent grassland less than 20 years-old and 200 kg C/ha for more than 20-years-old grassland (Gac et al., 2010, derived from Arrouay et al., 2002). The net GHG emissions were assessed by subtracting the total credits from the total GHG emissions of the production system.

The statistical analysis was performed using Minitab statistical software (13.31) for analysis of variance (ANOVA) and an Excel calculation spreadsheet for sample description and testing variances (F-test) and means equality (t-test).

3. Results and discussion

Table 1. Sample description: mean ± standard deviation for meat production (all farms; grass-based farms; grass and maize-based farms).

Variable	All farms (meat production part)	G	G-M
% farms (number)	100% (51)	53% (27)	47% (24)
Bovine Livestock Unit (BLU) - meat	210 ± 116	206 ± 133	214 ± 92
Farm area (ha*)	84 ± 48	87 ± 57	81 ± 34
Grassland (ha*)	76 ± 38	79 ± 40	73 ± 29
Maize (ha*)	5.3 ± 8.1	3.5 ± 9.8	7.5 ± 3.8
% maize/total area	5.9 ± 5.9	2.8 ± 5.1***[a]	9.9 ± 4.2***[b]
Livestock stocking rate (BLU/ha*)	2.54 ± 0.63	2.41 ± 0.73	2.69 ± 0.45
Meat production intensity (kg LW/ha*)	594 ± 270	605 ± 298	582 ± 235
Productivity (kg LW/BLU)	236 ±88	252 ± 97	218 ± 72

[a,b] Means quoted with different letters are significantly different at the level $p<0.0001$(***), LW: live weight, BLU: bovine livestock unit,
* ha: area dedicated to meat production, G: grass-based, G-M: grass and maize-based

Table 1 presents the key features of the two farm systems (G and G-M). The variability within the two systems is significant and is larger than that observed between them. Apart from the percentage under maize, the other characteristics of the two systems are similar (no significant difference). Both systems are intensive and their meat production intensity (kg LW/ha or kg LW/BLU) is comparable.

Table 2. GHG emissions sources and credits in kg eq. CO_2 per product (kg live weight) for systems based on grass (G) and grass and maize (G-M) (mean ± standard-deviation).

Emissions	kg eq. CO_2/kg LW	
	G	G-M
Total GHG emissions	18.22 ± 8,42	19.16 ± 6.16
Inputs		
Fertilizer	0.28±0.26**[a]	0.63±0.41**[b]
Feed	2.18±1.89*[a]	1.24±1.21*[b]
Energy	1.14±1.27	0.96±0.52
Other inputs	1.52±1.09	1.28±0.67
Cattle breeding		
Enteric fermentation	7.09±3.54	8.04±2.59
Manure storage	0.31±0.23*[a]	0.45±0.22*[b]
Manure spreading	0.52±0.39**[a]	0.86±0.43**[b]
Grazing	2.52±1.46	2.78±1.16
Crop production		
Soil	1.76±0.99	1.58±0.57
Mineral fertilization	0.29±0.27**[a]	0.65±0.44**[b]
Fuel	0.60±0.48	0.61±0.40
Credits		
C storage in grassland soils	2.63±1.57	2.14±0.75
Other credits	3.03±3.02	2.32±2.24
Net GHG emissions	12.57 ± 6.44	14.39 ± 6.25

[a,b] Means quoted with different letters are significantly different at the level $p<0.001$(**) or $p< 0.05$(*), LW: live weight, G: grass-based, G-M: grass and maize-based

On average, the farm's meat production activities resulted in emissions of 18.7 kg eq. CO_2/kg LW. Enteric fermentation, manure (production and use) and feed purchase, together, represented 70% of the total GHG emissions. The G system emitted 18.2 kg eq. CO_2/kg LW and the G-M systems emitted 19.2 kg eq. CO_2/kg LW.

There were large variations in the modelled GHG emissions and net GHG emissions around the mean, with the variability within one system higher than the variability between the two systems.

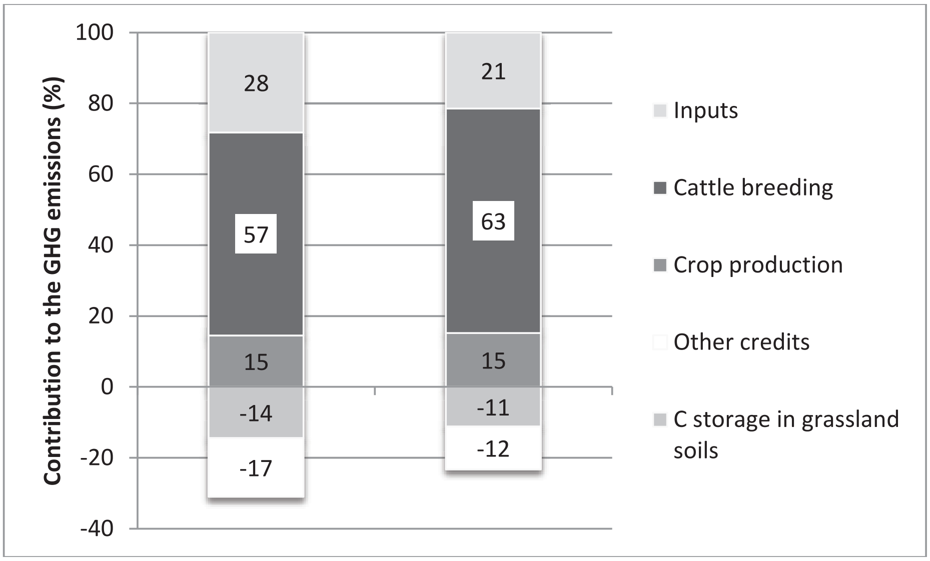

Fig. 1. Meat production credits and contribution (%) to GHG emissions

The difference between GHG emissions from the two systems reflected differences in:

- purchase and use of mineral fertilizer (more mineral fertilizer is needed for growing maize in G-M systems)
- purchase of feed (more feed is purchased in G systems than in G-M systems)
- manure storage and spreading (the livestock stocking rate is higher in G-M systems; 2.69 v. 2.41 BLU/ha)
- carbon storage under grassland (the area under grassland is greater in G systems; 79 ha v. 73 ha).

The total and net GHG emissions in kg eq. CO_2/kg LW for both systems, however, did not differ significantly due to compensation between the GHG sources and the high variability in the modelled GHG emission within the groups. The “systems” factor explained less than 1% of the variability in the modelled GHG emissions. The typology used was not adapted to show differences in GHG emissions.

When credits were included in the assessment (net GHG emissions expressed by kg LW), there was a reduction of the impact by 31% and 23% for the G and G-M systems, respectively. The carbon storage in grassland soils accounted for 59% (G) and 48% (G-M) of these reductions. There is still some debates within the scientific community about the use of a recognized value for carbon storage in grassland soils; the value used could have a significant impact on the net GHG emissions of suckler-cow systems based on grass (Gac et al., 2010). Taking account of the carbon credits could provide an opportunity to reduce emissions from cattle breeding systems.

The GHG emissions were influenced by the intensity of production (see

Fig. 2) and therefore by livestock stocking rate because those parameters were correlated. Other factors, such as bovine livestock unit (BLU), total area dedicated to meat production, area under grass and maize and percentage under maize, had no influence on the emissions.

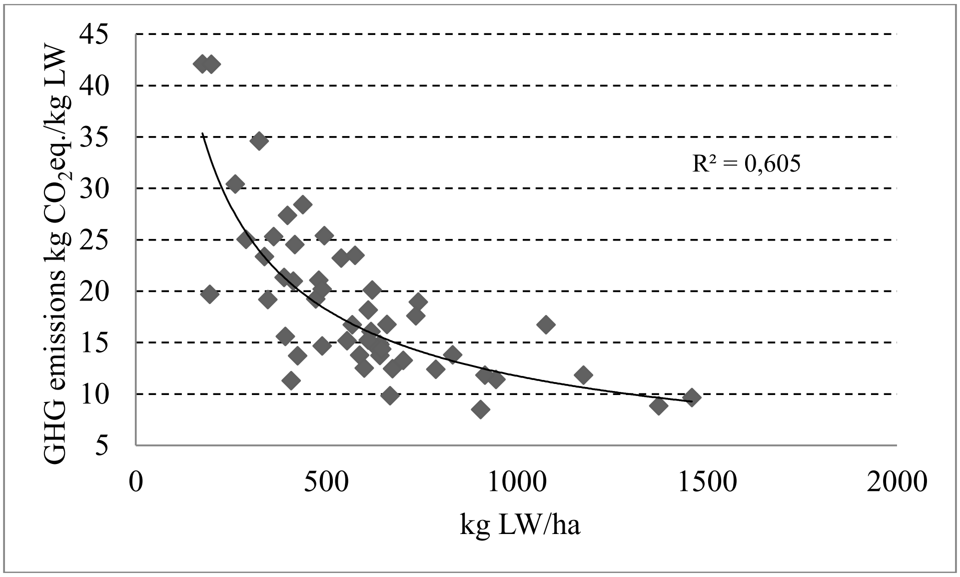

Fig. 2. Relationship between GHG emissions and production intensity (kg LW/ha) in kg CO_2 eq. / kg LW

The GHG emissions per product unit tended to decrease with production intensity, explained by the dilution of emissions on the product quantity.

This effect could be reinforced by a better rationalization of some inputs (e.g., energy), but the relationship was not linear and was tempered beyond a certain level (between 800-1000 kg LW/ha). Indeed, the increase of the productivity meets a limit: loss of the connection to the soil and strong dependence on inputs. For very intensive systems, every additional kg of meats is completely produced from standardized and imported inputs. With sufficient data, it would be possible to identify an optimum that allows a balance between productivity and environment.

A complementary approach could be to express the GHG emissions per ha in relation to production intensity in order to assess the impact of meat production on the environment (footprint), but in this case the farm hectarage used to produce the resource (feed) would need to be included in order to avoid erroneous assessments at farm level.

4. Conclusion

On average, in order to produce 1 kg live weight (LW), Walloon systems emitted 18.7 kg eq. CO_2. The differences between both systems (G and G-M) occurred in feed and mineral fertilizer purchase, in manure emissions and in mineral fertilizer application. There was a large variation in the assessed GHG emissions between and within the two systems but there is no effect of the feeding type (based on grass or grass and maize), this means that the typology used was not adapted to show differences in GHG emissions.

The GHG emissions per product unit tended to decrease with production intensity to a certain level of intensification from which the carbon footprint of meat remain steady, more data are needed to identity an optimum between productivity and environment.

Including carbon credits in the assessment resulted in a reduction of 31% and 23% in the carbon footprint of meat production for the G and G-M systems, respectively. These values need further investigation because the integration of carbon storage in grassland soils is still not unanimously recognized in GHG inventories, but this could be an important issue for grass-based suckler-cow systems.

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